The Total Photoabsorption Cross Section of ^{6,7}Li below π-threshold
Electweak Properties of Light Nuclei

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JG|U

MAX-lab

Outline

Motivation

- The use of few-body systems allows exact calculations of cross sections to be made.
- Allows different NN-potential models to be tested and compared with measured data.
- For ^{6,7}Li calculations exist from S. Bacca which employ the LIT.
- The calculations predict a broad resonance peak for both Li isotopes with the ^{7}Li cross section having $\sim$0.5 mb more strength than ^{6}Li one in the peak region.
- Can investigate the nature of resonances in relation to possible cluster arrangements.
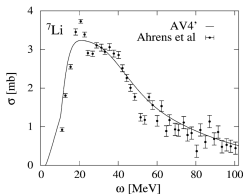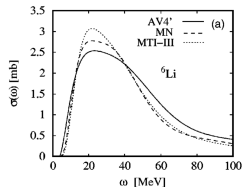
Previous Measurements: ^{6}Li
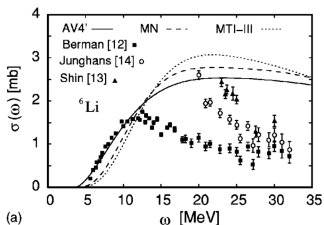
Curves from S. Bacca *et al.*, Phys. Rev. C. **69** (2004) 057001

Data from:

- B. L. Berman *et al.*, Phys. Rev. Lett. **15** (1965) 727

- Y. M. Shin *et al.*, Phys. Lett. **55B** (1975) 297

- G. Junghans *et al.*, Z. Phys. A **291** (1979) 353

- Data shown are for exclusive reactions.
- Curves are for the total photoabsorption cross section using different *NN*-potentials.
- Agreement is good up to $\sim$10 MeV.
  - In this region reactions to all final states were detected.
- No previous measurements of total photoabsorption cross section for ^{6}Li.

Previous Measurements: ^{7}Li

- A previous measurement of the total photoabsorption cross section for ^{7}Li exists by J. Ahrens *et al.*, (Nucl. Phys. **A251** (1975) 479)

- Calculations for ^{7}Li by S. Bacca *et al.* Phys. Lett. B, **603** (2004) 159

- Reasonable agreement is seen between the measured data and the calculations.

- Of interest with ^{7}Li is the peak in the data at $\sim$20 MeV.
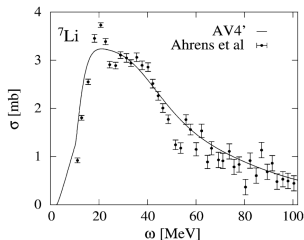
Principle of Measurement
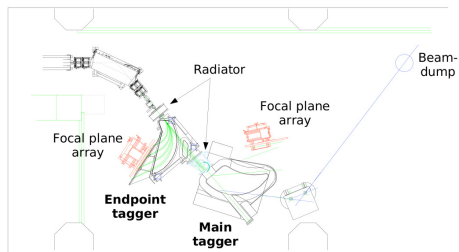
- Use attenuation method to measure cross section.

$$N(E_\gamma) = N_0(E_\gamma)\mathrm{e}^{-n\sigma_{tot}(E_\gamma)}$$

- where n is the number of nuclei and $\sigma_{tot}(E_\gamma)$ is the total photoabsorption cross section.

- $\sigma_{tot} = \sigma_n + \sigma_a$ where σ_n is the nuclear cross section and σ_a the atomic cross section.

- Measurement of the tagging efficiency with and without the target material in place and determining the ratio allows one to determine the total cross section.

$$\sigma_n = \left(-\frac{1}{n}\ln\frac{N(E_\gamma)}{N_0(E_\gamma)}\right) - \sigma_a$$

MAX-Lab

- Mainly a synchrotron light facility with three storage rings of different energies.
- Nuclear physics is one beam line and uses the MAX 1 ring as a stretcher.
- Beam injected into MAX 1 at a rate of about 10 Hz and then stretched over a time of about 100 ms.

MAX-Lab: Nuclear Physics

Tagging spectrometers

- Available beam energies range from 142 - 200 MeV for currents up to 30 nA with a 50% duty factor.
- The main tagger was used for this measurement.
- To get lower intensities beam is mist-steered before the linacs.

Experimental Set-Up

- A schematic of the experimental set-up is shown below.
- A BaF$_2$ detector was used for the photons.
  - Consisted of 4 optically connected $8 \times 8 \times 25$ cm^3 crystals each with their own PMT.
- Targets were 2 m long 2 cm diameter and housed in Al tubes:
  - ^{6}Li ($95.63 \pm 0.15\%$).
  - ^{7}Li ($92.43 \pm 0.15\%$).
- Three collimators were used to make sure the beam would not hit the sides of the targets and to clean up small angle scattered particles.

Distances in mm
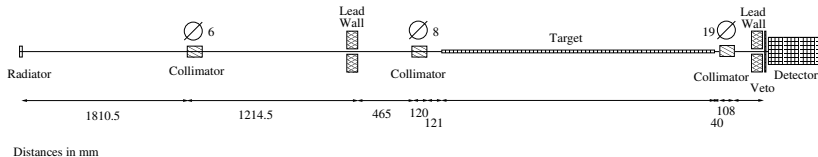
Experimental Set-Up
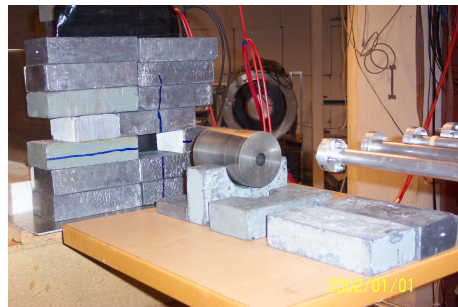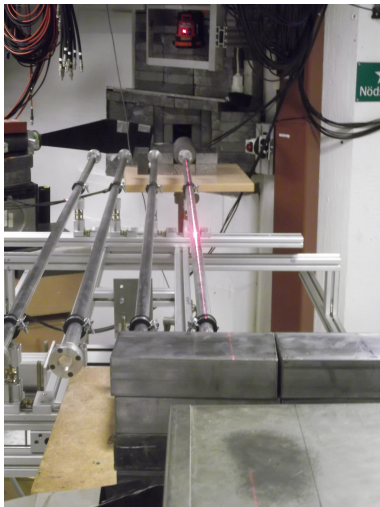
- Views upstream from the BaF$_2$ detector and of the shielding for this.

Measurement Conditions

| Data Set	Year	Radiator	E_e [MeV]	$E_{\gamma low}$ [MeV]	$E_{\gamma high}$ [MeV]	e^- rate
0	2009	150 μm Al	164.76	16.76	71.58	low
1	2009	150 μm Al	164.76	16.76	71.58	low
2	2009	150 μm Al	164.76	60.77	99.98	low
3	2011	300 μm Al	164.76	10.78	65.94	low
4	2011	25 μm Al	164.76	10.78	71.58	high
5	2011	25 μm Al	164.76	10.78	71.58	high
6	2011	25 μm Al	164.76	8.60	63.66	high
7	2011	25 μm Al	164.76	8.60	63.66	high
8	2011	50 μm Al	164.76	61.22	100.36	high

- Data Sets separated by different run conditions and longer breaks in the beam time.

Focal Plane TDC Spectrum

- Data shown is that from the empty target setting from data set 4, similar situation for other target settings.

- Structure seen in the spectrum is from the beam and has a 108 ns period from MAX I ring circumference.

- For 2009 data there is also a 330 ns structure from the beam kicker.

- Accidental coinicidences are $\sim 0.4\%$ of prompt peak for high rate data and $\sim 0.2\%$ for low rate data.
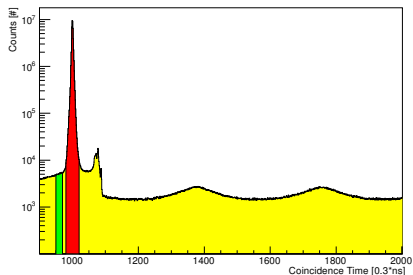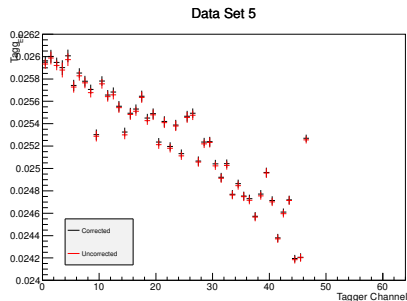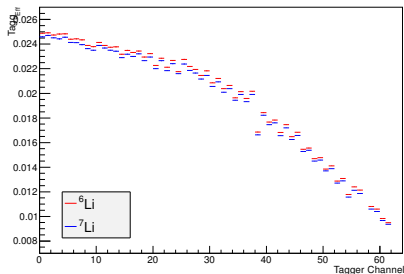
Focal Plane TDC Spectrum
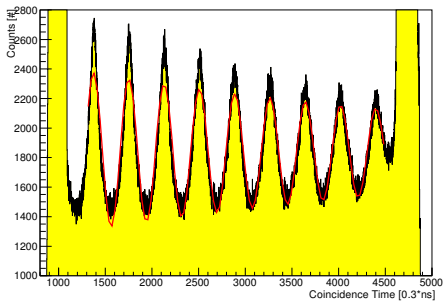
- Trying to fit the background structure to remove it for an accidental subtraction.
- Can't yet completely describe the data.

Tagging Efficiency

- Statistical errors included in the plots.
- Correction for background in the hall applied to the data.
- Dip in efficiency is partly due to an effect of beam collimation.
- Can see a difference between the data sets for the two Lithium targets.
- Effects of focal plane efficiency divide out when cross sections determined.

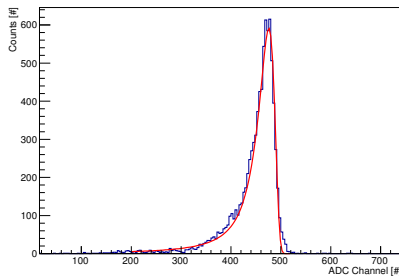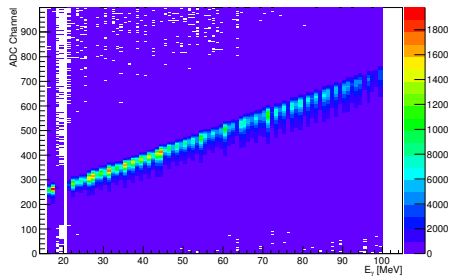# Tagging Efficiency: File Selection

2009

Tagging Efficiency, Data Set 1: ^{6}Li Target: Channel 34

2011

Tagging Efficiency, Data Set 8: Empty Target: Channel 34
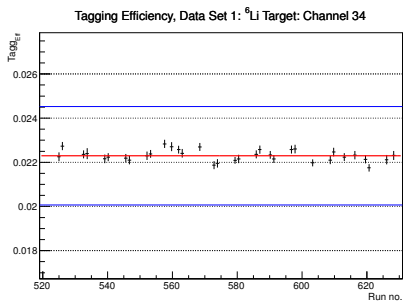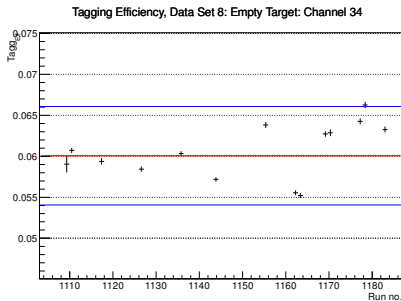
- MAX-Lab beam is not very stable.
- Used individual channel tagging efficiency to select good files for each target setting: used a cut of $\pm 10\%$ of fit to mean.
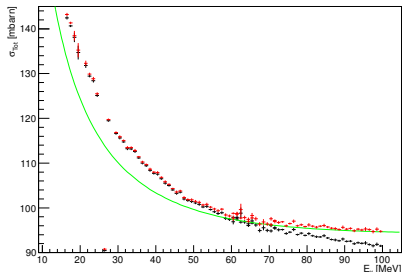
BaF$_2$ Pulseheight Cut: 2009 Data

BaF$_2$ ADC sum vs. E$_\gamma$: all data

- Clear relationship between pulseheight and photon energy as expected.

- The peaks for individual channels were fit with a Landau and this used to define cuts.

Effect of BaF$_2$ Cut: ^{7}Li 2009 Data

- The BaF$_2$ cut was improtant particularly at higher energies.
  - Black points: before cut.
  - Red points: after cut.
- The pulseheight cut needs to be looked at it more detail to properly understand it.
  - Look at change in cross section as a function of cut on a channel-by-channel basis.
- Further corrections still need to be applied.

- Total cross section determined taking into account different percentages of Li isotopes in targets.
- Green curve is the atomic cross section taken from NIST XCOM program.
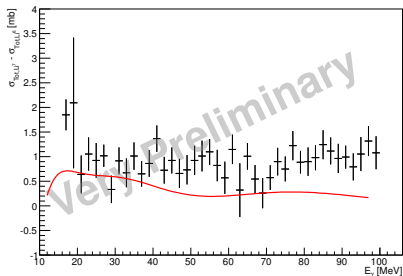
## 2009 Data: Li Uncorrected Nuclear Cross section
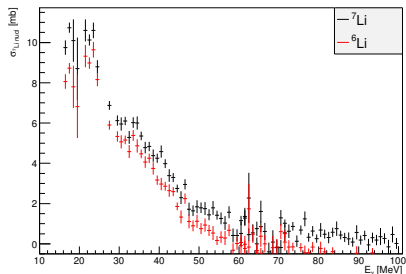
- Cross Sections much larger than expected. We still need to apply some corrections for in-scattering within the target and other possible effects from the detector set-up.

- Need to use a Geant4 Simulation for this and to better understand other aspects of the data.

2009 Data: Li Total Cross Section Difference

- Just taken the difference of the total cross sections for the two isotopes.
- Many corrections that affect the final nuclear cross sections will cancel out.
- Red curve from S. Bacca and uses the AV4 NN potential.
- Calculations underpredict the experimental data.

2009 Data:^{6}Li Nuclear Cross section?
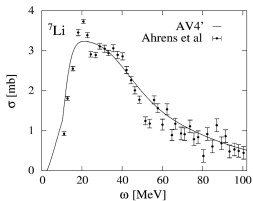

- The previous ^{7}Li measurement data well described by the calculations. If one assumes all is correct then taking the difference of these would allow us to know the size of the corrections we have to apply.
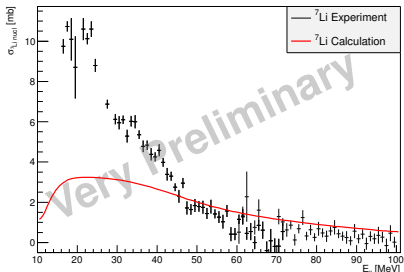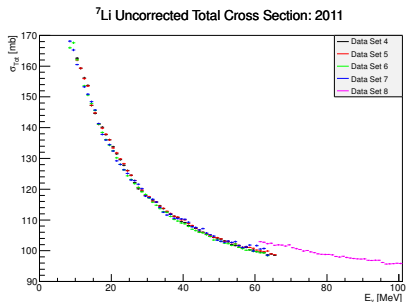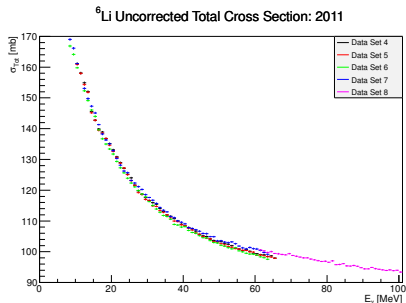
- This could then be subtracted from the ^{6}Li data to leave a semi-corrected nuclear cross section.

- Tried this to get a rough result, not to be taken seriously.

^{6}Li Nuclear Cross Section?: 2009
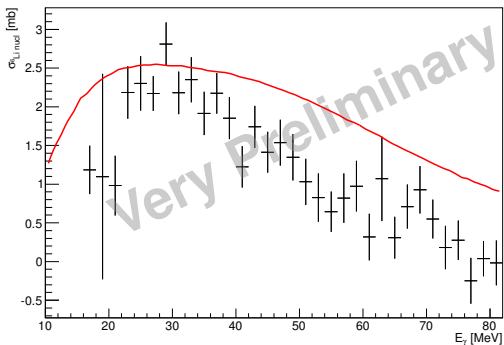
- This should not be taken seriously!
- The data need to be fully analysed before a proper comparison can be made.
- Curve Uses AV4' *NN*-potential.

Li Uncorrected Total Cross Section: 2011

- Data sets are reasonably consistent with each other.
- Potential problems with set 8 due to issues with the beam stability.

Summary and Outlook

- The ongoing analysis has so far produced some promising results, particularly for the 2009 data.
- The normalisation of the data and systematic effects of the set-up need to be studied in detail.
- Development of a Geant4 simulation has been started which will include all aspects of the experimental set-up.
- Analysis of the 2011 data and re-analysis of the 2009 data ongoing.

Thanks

Thank you for your attention.

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